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PHYTOTOXICOLOGY INVESTIGATIONS IN THE CORNWALL AREA OF ONTARIO IN THE VICINITY OF THE REYNOLDS METALS COMPANY (RMC), AND THE ALUMINUM COMPANY OF AMERICA (ALCOA), MASSENA, NEW YORK - 1986

Air Resources Branch

Phytotoxicology Section

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EXECUTIVE SUMMARY

A Federal-Provincial study with participation by several government agencies, including the Phytotoxicology Section, Ontario Ministry of the Environment, has been ongoing in the Cornwall area for several years.

Phytotoxicology investigations, involving vegetation sampling and injury observations, to assess the impact of airborne fluoride emissions from the Reynolds Metals Company (RMC) and from the Aluminum Company of America (ALCOA), both in Massena, New York, on vegetation in the Cornwall and Long Sault areas of Ontario, have been conducted during each growing season since 1969 and 1976, respectively.

The results of the most recent RMC and ALCOA survey study findings in 1986 are presented in this report.

In the RMC survey area, which includes the St. Regis Indian Reserve on Cornwall Island and extends to the north and northeast of the City of Cornwall, the highest fluoride levels in 1986 were, as in earlier years, detected in vegetation in the south shore bridge area (the immediate impact area) of the island, with levels decreasing sharply with increasing distance from this area. Fluoride levels in maple foliage collected from Cornwall Island in August and in forage collected monthly (May - October) generally were reduced in 1986, being amongst the lowest to be detected since the survey began. In contrast with previous years, none of the monthly and six-month fluoride means for forage exceeded the MOE Ontario forage criteria. In 1986, the

severity of F-like injury to vegetation also was less severe overall than in 1985, with the most adverse effects (as in all past years) being observed in or near the island's south shore bridge area which is directly across the river to the northeast of RMC.

Foliar fluoride levels in the Long Sault survey area, to the north and northeast of ALCOA, also were reduced in 1986, being amongst the lowest to be detected since the start of the survey. In August 1986, as in previous years, F-like injury was observed only on wild grape foliage, and the injury observed throughout the survey area was very light overall.

Upon examination of the 1986 weather data for the Cornwall area and the 1986 air monitoring program results on Cornwall Island in the RMC survey area, it is believed that weather variations were largely accountable for the decrease in fluoride contamination found in both the RMC and ALCOA survey areas in 1986. The reduced aluminum production at ALCOA since October 1985 likely contributed to the decrease in foliar fluoride contamination in the Long Sault area.

SOMMAIRE

Depuis quelques années se déroule dans la région de Cornwall une étude fédérale-provinciale à laquelle participent plusieurs organismes gouvernementaux, dont la Section de phytotoxicologie du ministère de l'Environnement de l'Ontario.

Des enquêtes phytotoxicologiques, comprenant des prélèvements d'échantillons et l'observation des dommages, ont été menées pendant la saison de croissance pour déterminer l'effet sur la végétation des régions de Cornwall et de Long Sault, depuis 1969 et 1976 respectivement, des émissions de fluorure dans l'atmosphère de deux sociétés situées à Massena (New York), la Reynolds Metals (RM) et l'Aluminum Company of America (ALCOA).

Les résultats des études les plus récentes effectuées en 1986 sur les émissions de la RM et de l'ALCOA figurent dans le présent rapport.

Dans la région de la RM, qui comprend la réserve indienne de St. Regis sur l'île de Cornwall et qui s'étend au nord et au nord-est de la ville de Cornwall, les concentrations les plus élevées de fluorure en 1986 ont été relevées, comme pour les années précédentes, dans la végétation de la rive sud de l'île près du pont (la principale zone touchée), et ces concentrations diminuaient rapidement avec la distance. Les concentrations de fluorure mesurées dans le feuillage d'érables recueilli dans l'île de Cornwall en août et dans le fourrage recueilli tous les mois (de mai à octobre) ont connu une diminution générale en 1986 et se situent parmi les plus basses depuis le début de l'enquête. Contrairement aux années précédentes, aucune des concentrations de fluorure dans le fourrage mesurées sur un mois et sur six mois ne dépassait les valeurs préconisées par le MEO. En 1986, les dommages causés à la végétation et attribuables au fluorure étaient dans l'ensemble moins graves qu'en 1985; comme par le passé, les effets de la pollution étaient le plus visibles dans les environs du pont de la rive sud de l'île, qui est situé directement au nord-est de la RM, de l'autre côté de la rivière.

Les concentrations de fluorure dans la région de Long Sault, au nord et au nord-est de l'ALCOA, étaient également réduites en 1986, et sont parmi les plus basses depuis le début de l'étude. En août 1986, comme par le passé, des dommages attribuables au fluorure n'ont été relevés que sur du feuillage de vigne, et ces dommages étaient dans l'ensemble très mineurs dans toute la zone étudiée.

Après examen des données météorologiques de 1986 pour la région de Cornwall et des résultats du programme de surveillance de la qualité de l'air mené en 1986 dans l'île de Cornwall et dans la région de la RM, il semble que la baisse de la pollution par le fluorure dans les régions de la RM et de l'ALCOA en 1986 soit attribuable en grande partie aux variations climatiques. En outre, la diminution de la production d'aluminium à l'ALCOA depuis octobre 1985 a probablement contribué à la baisse de la contamination du feuillage par le fluorure dans la région de Long Sault.

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PHYTOTOXICOLOGY INVESTIGATIONS IN THE CORNWALL AREA OF ONTARIO IN THE VICINITY OF THE REYNOLDS METALS COMPANY (RMC), AND THE ALUMINUM COMPANY OF AMERICA (ALCOA), MASSENA, NEW YORK - 1986

I. INTRODUCTION

A Federal-Provincial study with participation by Environment Canada, Agriculture Canada, National Health and Welfare, Indian and Northern Affairs and the Ontario Ministry of the Environment was established in the Cornwall area in 1975. Prior to this time, the Phytotoxicology Section had been conducting annual vegetation assessment programs and responding to complaints concerning the adverse effects of airborne fluoride emissions on vegetation and cattle since 1969. The source of the fluoride emissions was identified as the Reynolds Metals Co., located in Massena, New York. The study was broadened in 1975 in view of the transboundary nature of the emissions and their impact on the St. Regis Mohawk Indian Reserve on Cornwall Island.

In 1976, the Phytotoxicology Section also initiated vegetation survey activity in the Long Sault area, downwind of the larger Aluminum Co. of America plant (ALCOA) located in Massena, N.Y., to the west of the RMC plant.

Both of these vegetation assessment programs have been ongoing in the Cornwall and Long Sault areas without interruption since 1969 and 1976, respectively.

The results of the most recent 1986 study findings are presented in this report.

II. RMC Assessment Program

A. Objective

The primary objective of the RMC assessment program was to determine the degree and extent of fluoride contamination and injury to vegetation and to compare these findings with previous years' results.

B. Samples Collected for Chemical Analysis

Maple Foliage

In mid-June, mid-July and mid-August, tree foliage (Manitoba or red maple or both) was collected from Cornwall Island in the south shore immediate impact area to the west and east of the International Bridge, as well as from the Noah Point property (red maple) to the neighbouring northeast. In late August, Manitoba maple foliage was sampled from exposed middle branches of all regular collection sites sampled in 1985 across Cornwall Island and the Ontario mainland to the north and northeast of RMC. Overall, tree foliage sampling in the RMC survey area during 1986 (see Figures 1 & 2) consisted of the following: red maple at three sites in June, July and mid-August; Manitoba maple at Sites 21 and 1 in June and July, respectively; and Manitoba maple at 17 sites in late August.

Pine Needles

In mid-September, current year's (1986) Eastern white pine needles were collected from the same pines sampled in previous years in the south shore area to the west and east of the bridge and from the more remote Elijah Benedict property near the centre of the island (see Figure 2).

Forage

Forage was collected at all sites sampled in 1985. As in previous years since 1978, the forage sites were sampled monthly during May through October. Prior to 1978, forage sampling was performed only in June, July and August. Overall, during the 1986 growing season, forage was collected from twelve sites on Cornwall Island and from three sites on the Ontario mainland, including a remote site near Lunenburg (see Figure 1).

C. Foliar Samples Collected for Histological and Pathological Examination During 1986

See attached Table 8.

D. Processing of Samples Collected for Chemical Analysis

All samples for chemical analysis were processed in the Phytotoxicology processing laboratory and then were submitted for analysis on a dry weight basis to the Inorganic Trace Contaminants Section, Laboratory Services Branch, MOE.

The regular Manitoba maple foliage collection in late August was processed on a washed and unwashed basis. The other samples collected during 1986, including the forage collections, were processed as unwashed samples. All samples were analyzed for fluoride. The unwashed samples of the regular August Manitoba maple collection were additionally analyzed for aluminum and sodium.

E. Visual Injury Assessment Program

As in previous years, injury assessments on native vegetation (wild grape, cherry, maple, pine), cultivated grape, vegetable crops and gladiolus were performed in the survey area during June to August, with the pine needle injury assessments being conducted through to mid-September.

III. Results of 1986 Assessment Program

A. Analytical Results for Maple Foliage and Pine Needles

Maple Foliage

As in previous years, the highest foliar levels were detected in the south shore bridge area (east of bridge) to the immediate northeast of RMC (Tables 1 & 4). In late August, Manitoba maple foliage was collected at numerous sites throughout the survey area and the corresponding fluoride results, as in previous years, displayed a pattern of decreasing concentration with increasing distance from the south shore bridge area (Table 1). In this area, the fluoride level at Site 1 (159 ppm) in August was much lower than the July level (384 ppm) which was the highest fluoride level to be detected in vegetation in the survey area during 1986. Fluoride levels in red maple foliage collected in the south shore immediate impact area and on the slightly more remote N. Point property in June, July and August also were found to be the highest in July (Table 4).

As shown in Tables 1 and 4, fluoride levels in unwashed Manitoba and red maple foliage samples collected in August, 1986 generally were reduced compared to the corresponding 1985 levels, and were amongst the lowest to be detected since the survey began. The average contribution of

particulate surface contamination to total F loading of Manitoba foliage at most sites in August also was reduced in relation to earlier years' (Table 2) results.

The unwashed aluminum and sodium results for the Manitoba maple foliage collection in late August are compared to earlier years' data in Table 3. As with fluoride, the highest aluminum and sodium levels were detected in the south shore immediate impact area (Site 1), and foliar levels of both elements at most sites were reduced compared to earlier years' (1982-85) results.

Pine Needle Results

As with maple foliage, the highest fluoride levels in unwashed current years' Eastern white pine needles collected from Cornwall Island in 1986 were detected in the south shore bridge area just east of the bridge. In contrast to the maple results, fluoride levels at all pine needle sites in September were slightly higher than the corresponding 1985 results. However, levels in 1986 were reduced compared to the corresponding 1982 and 1984 results (see Table 5).

B. **Comparison of Unwashed Maple Foliage Results with Guidelines Established by the Phytotoxicology Section**

Fluoride

The mean fluoride level detected at all maple collection sites in June (4 sites), July (4 sites) and mid-August (3 sites) and at 14 of the 17 regular Manitoba maple sites in late August exceeded the 15 ppm "upper limit of normal" guideline for a rural area. Unwashed fluoride levels at all maple sites sampled in mid-July and mid-August exceeded the urban foliage guideline (35 ppm). However, only 3 of the 17 regular Manitoba sites in late August exceeded the urban

guideline, as compared to 7 sites in late August of 1985, 11 sites in 1984 and 10 sites in 1983.

Aluminum and Sodium

As in previous years, foliar levels of aluminum at all Manitoba maple collection sites in late August, including the highest level which was detected at Site 1 (127 ppm), were well below the respective 500 ppm guideline for unwashed foliage.

The 50 ppm rural guideline for sodium was exceeded at 11 of the 17 Manitoba maple sites in late August, compared to 15 sites in 1985, 16 sites in 1984 and 15 sites in 1983. In contrast with previous years (1982-85), none of the sodium results, including the highest level which was detected at Site 1 (137 ppm), were found to exceed the respective urban guideline (350 ppm).

C. Analytical Results for Forage

As in earlier years, the highest monthly fluoride levels in unwashed forage were detected at the Bridge site in the south shore immediate impact area just east of the bridge. As with maple foliage and pine needles, fluoride levels in forage decreased with distance from this area (Table 6).

Comparison of the six-month (May - October) fluoride growing season means for 1978 to 1986 (Table 6), and of the three-month (June - August) means since forage sampling began in 1969 (Table 7), revealed that levels of fluoride at most forage sites in 1986 were the lowest ever to be detected in the RMC survey area.

D. Comparison of Forage Results with MOE Ontario Forage Criteria

Exceedances of the MOE forage criteria were documented in most previous years at the Bridge site. However, in 1986, there were no exceedances at any of the forage collection sites, compared to a single exceedance in 1985, eleven in 1984, four in 1983 and three in 1982.

E. Injury Assessment Findings

Wild Grape

By August, the most severe F-like injury to wild grape plants on Cornwall Island, as in previous years, was observed in the south shore bridge area (immediate impact area). To the west of the bridge, the most adverse injury was observed on well exposed grape vines growing next to the river edge. To the east of the bridge, the most severe injury was observed on well exposed grape foliage growing in a tree just south of the horse paddock on the Martin property next to the river. In both areas, the injury severity, for the most part, was trace (>0% - 1%) to light (2% - 10%). A few of the more adversely affected mature leaves exhibited borderline light (2% - 10%) to moderate (11% - 35%) injury, with the injury being light overall. All other grape plants that were injured in the south shore immediate impact area displayed trace (>0% - 1%) injury, with the injury observed throughout this area (east and west of bridge) being very light overall during 1986.

Beyond this area to the northeast, trace (>0% - 1%) injury was observed in August on affected wild grape plants through to the E. Benedict property (centre of the island). Other grape

sites examined in the survey area (west and east of bridge) during June through August exhibited virtually no injury.

F-like injury to wild grape plants in the south shore immediate impact area to the west of the bridge, where the most adverse injury has been observed in recent years, generally was less severe than in 1985.

Staghorn Sumac

Staghorn sumacs growing in the south shore immediate impact area and on the neighbouring Lillian Point property to the northeast exhibited peculiar foliar injury similar to that described in previous reports (1983-1985). The injury observed throughout the immediate impact area (west and east of bridge) ranged from trace (>0% - 1%) to severe (> 35%), with the overall injury to individual thickets, for the most part, being light (2% - 10%) through to August. The foliar injury observed on the Point property also was light. The most pronounced injury was observed in the early summer when both young and mature leaves were affected. In mid-August, the injury was observed primarily on mature leaves, with the younger foliage on most affected sumacs being green and healthy.

The absence of the injury on more remote thickets suggested that RMC emissions had contributed to the observed sumac injury in the immediate area of RMC. However, the negative histology results (Table 8) did not confirm that fluoride emissions were the primary cause.

Compared to previous years' observations, sumac thickets in the south shore immediate impact area were less severely injured in 1986.

Cherry and Plum Trees

Observations in the immediate impact area in June revealed F-like foliar injury on choke and pin cherry trees to the west and east of the bridge and on a young black cherry growing adjacent to the river to the west of the bridge. Histological analysis confirmed that the injury to choke cherry was typical of fluoride (Table 8).

Injury to the black cherry in June was in the trace (>0% -1%) to moderate (11% - 35%) range, being light (2% - 10%) overall, with the injury to affected choke and pin cherry trees being trace (>0% - 1%) overall. As in 1985, cherry foliage in the immediate impact area exhibited the most pronounced F-like injury in June. By August, affected choke and pin cherry trees displayed only traces of F-like necrosis and/or only leaves with missing tissue at the tip and/or margins. During the summer, the black cherry in the south shore area displayed several injured leaves with the most severe injury being observed on mature leaves through to August. In August, the injury to a young choke cherry and a young pin cherry growing near the black cherry was very light, suggesting that fluoride emissions were not solely responsible for the injury to the young black cherry. As in 1985, the black cherry trees on the more remote A. Boots property displayed several leaves with a spotty disease-like injury pattern. The vigour of these trees appeared to be improved in 1986 compared to 1985.

In addition, in June, F-like injury was observed on plum foliage in the plot the writer established in the south shore area just west of the bridge in 1984. Similar foliar injury also was observed on plum trees on the A. Boots property to the neighbouring northeast in July. At both

locations, only some leaves were affected and the injury overall was either trace (>0% - 1%) or very light (2% - 10%).

By August the mature plum tree on the N. Point property exhibited most leaves with light to severe (>35%) brown, marginal necrosis. However, as in 1985, the area observations did not suggest that fluoride emissions were the primary cause.

The severity of foliar injury observed on cherry and plum trees in the south shore immediate impact area in 1986 was fairly similar to 1985, with the injury possibly being slightly reduced in 1986.

Manitoba Maples

In June, Manitoba maples throughout the survey area were green and healthy.

In July and August, as in 1985, Manitoba maples in the south shore immediate impact area, including collection Site 1 just east of the bridge, displayed some older leaves with marginal chlorosis and/or brownish necrosis.

Moreover, the shoots sampled at Site 1 in August had a tuft of foliage at the terminal end as several of the older leaves had previously abscised. In August, this injury pattern at other Manitoba maple sites was appreciably less pronounced, suggesting that RMC emissions may have contributed to the premature leaf senescence at Site 1.

Red and Silver Maples

During the summer, only traces (>0% - 1%) of possible F-like foliar injury (blackish tip necrosis) were observed on red

maples at the south periphery of the two woodlots in the south shore immediate impact area (west and east of bridge) and on neighbouring properties (Lillian Point, Noah Point, A. Boots) to the northeast of RMC.

Marginal reddish-orange to brown necrosis was more prominent, being present by July on several leaves of red maples in the woodlot just east of the bridge and on the L. Point property, with the injury at both locations being light (2% - 10%) for the most part. Only a few leaves at the other sites displayed this type of injury.

The reddish-orange brown necrosis was first noticed on red maple foliage in the east bridge woodlot in June. As the foliar fluoride level detected at this site in June generally was low (29 ppm) and as the corresponding histological results were negative, it would not appear that this type of injury was not directly related to fluoride emissions.

In general, red maples in the immediate area of RMC displayed better vigour in 1986 than in recent years.

During June through August, no obvious F-like injury was observed on the young silver maples along the north limit of the A. Boots garden. In 1985, trace (>0% - 1%) injury was observed on some of these trees.

Trembling Aspen and Serviceberry

In June, trembling aspens growing in the south shore immediate impact area (west and east of bridge) exhibited blackish necrosis at the tip and/or margins of some leaves, with the injury being trace (>0% - 1%) to light (2% - 10%). Blackish necrosis also was observed on trembling aspens in this area during 1985. However, histological analysis

(Table 8) did not confirm that fluoride emissions were the primary cause in 1986.

By July, distinct foliar injury (dark reddish-brown to blackish marginal and/or tip necrosis on several leaves) also was present on the small serviceberry tree that had exhibited injury in 1985, growing in the immediate impact area to the west of the bridge. Missing tissue at the leaf tip and/or margins of several leaves, as well as cupping, also were observed in both July and August. The injury to this tree on both occasions was light (2% - 10%) overall.

Pine Needle Assessment

The young red pines on the N. Point property to the neighbouring northeast of the south shore immediate impact area displayed several current year's needles with F-like reddish tip necrosis, with the average injury severity, as in 1984, being light (2% - 10%) in 1986. In 1985, the injury was less severe, with trace (>0% - 1%) injury being observed on only some needles on a single red pine at this location.

The observations in July and August did not reveal any F-like injury on current year's needles on other red pines or on Scot's pines examined in the survey area. The current year's Eastern white pine needles collected from the south shore area woodlots (west and east of bridge) and from the Elijah Benedict property (centre of island) in September also did not display any unusual injury.

Histological analysis of the injured current year's red pine needles collected from the N. Point property in September 1986 revealed that the injury was typical of fluoride (Table 8).

Cultivated Grape

Cultivated grape plants were examined monthly (June-August) on the A. Boots property which neighboured the south shore bridge area, and in August on the more remote Earny Benedict (centre of island) and A. Lazore (east end of island) properties (see Figure 3).

On the Boots property, trace (>0% - 1%) injury on cultivated grape foliage was initially observed in July. In August, the grape vines examined at all sites displayed only a few mature leaves with a trace amount of reddish tip injury.

The injury observed at these sites in 1986 was comparable to 1985.

Garden Crop Assessment

Foliar assessments on garden crops on the island in mid-July and mid-August did not reveal any peculiar injury, with sweet corn plantings closest to RMC being notably free of the injury observed in previous years (1984 and 1985).

Gladiolus Assessment

Mixed glads were examined on the Lillian Point property to the neighbouring northeast of the south shore bridge area in both July and August and on the Jacobs property (next to P. Caldwell forage site - see Figure 1) in August. In 1986, no glads were present on the Martin property (south shore, immediately east of bridge) or on the G. Charrow or Mrs. Leaf properties (Figure 3).

In both July and August, the glads on the Point property displayed F-like reddish injury extending down one or both

sides of older leaves, with the injury severity in August being light (2% - 10%) overall. In August, the glads on the Jacobs property exhibited only a few older leaves with trace (>0% - 1%) tip injury.

F. Results of Histological and Pathological Examinations

Results of histological and/or pathological examination of foliage samples collected from the RMC survey area during 1986 are shown in Table 8. Fluoride injury to choke cherry in the south shore bridge area and to red pine on the N. Point property was confirmed. The injury to plum foliage sampled from the N. Point property and to the plum and black cherry leaves collected from the Boots property had some similarity to fluoride, but as these samples were found to be diseased, it cannot be certain that fluoride was involved in the injury development.

IV. RESULTS OF ENVIRONMENT CANADA AIR MONITORING PROGRAM AND METEOROLOGICAL ASPECTS - 1986

As in 1985, ambient fluoride was monitored only at Station B - Benedict Farm (centre of Cornwall Island) and a wind recorder was maintained at Station C (west end of island) during April through October, 1986 by Environment Canada.

In 1986, Environment Canada found that gaseous and particulate fluoride levels at Station B were slightly increased relative to the low 1985 levels and that wind direction was predominantly from the west (see attached synopsis taken from Environment Canada's 1986 report).

The percentage of S, SW and W winds, and frequency and amount of rainfall recorded at the Ontario Hydro climatic station, Cornwall

during May through August are compared to earlier years' data in Table 9.

This table shows that 1986 was the wettest year on record (1978-86), with the total amount and frequency of rain received each month (May-August) being above the respective norms, particularly in July. Table 9 also shows that the percentage of SW wind blowing into the Cornwall area during 1986 (especially during July) was lower than that recorded in 1985 and most earlier years.

In light of both the air monitoring data and the meteorological data for the Cornwall area, with the 1986 climatic data revealing an increase in rainfall coupled with a reduction in SW wind blowing into the survey area, it is suspected that the decrease in fluoride contamination found in the RMC survey area during 1986 was primarily weather related.

V. ALCOA ASSESSMENT PROGRAM - 1986

A. Objective

The main objective of the 1986 ALCOA assessment program was to determine the degree and extent of fluoride contamination and injury to native vegetation and to compare these findings with previous years' results.

B. Sampling and Injury Assessment Programs

During late August (as in other years), triplicate samples of Manitoba maple foliage were collected from the exposed side at six collection sites in the Long Sault area to the north and northeast of ALCOA. All samples were processed on a washed and unwashed basis and were submitted on a dry weight basis to the Inorganic Trace Contaminants Section, Laboratory

Services Branch, MOE, to be analyzed for fluoride, aluminum and sodium.

Also during August, sensitive vegetation (e.g. wild grape, pines) in the survey area was examined for fluoride injury.

C. Status of ALCOA Emissions

In October 1985, and again in May, 1986 ALCOA reduced aluminum production by shutting down old potroom lines. This has resulted in a decrease in daily product output from about 500 Tons/day to about 365 Tons/day. As both of these lines were utilizing less efficient F collection technology than the remaining potroom line the reduction in F emissions probably has been greater then the 27% productivity cutback value.

D. Analytical Results (Comparison with Previous Years' Results and with MOE Guidelines)

Unwashed fluoride levels at all foliar collection sites were reduced in 1986 compared to earlier years' (1983-85) results, and were amongst the lowest to be detected in the Long Sault area since the survey began in 1976. As in more recent years (1982-85), the highest mean fluoride levels were detected in unwashed foliage collected at maple Site 7 (27 ppm), located 9.6 km northeast of ALCOA (see Table 10 and Figure 2).

The "upper limit of normal" guideline for fluoride in rural foliage (15 ppm) was exceeded only at one site (Site 7) in 1986, compared to 6 sites in 1985, 5 sites in 1984 and 6 sites in 1983. In contrast with previous years, none of the foliar fluoride results were found to exceed the urban foliage guideline (35 ppm), this being the first time since the survey began that there were no exceedances of the 35 ppm guideline. In all previous years, the guideline was exceeded

at one or two sites, except for 1984 when exceedances occurred at four locations. The corresponding aluminum (14 - 42 ppm) and sodium (16 - 41 ppm) results were in the range shown in parentheses and, as in 1984 and 1985, there were no exceedances of the "upper limit of normal" guidelines for aluminum (500 ppm) and sodium (50 ppm - rural; 350 ppm - urban).

E. Visual Findings

In 1986, as in previous years, F-like injury was observed only on wild grape foliage (trace (>0 - 1%) tip necrosis of occasional leaves).

VI. SUMMARY OF RMC AND ALCOA SURVEY FINDINGS - 1986

A. RMC Survey

The main findings for the RMC survey area can be summarized as follows.

(1) RMC emissions, as in previous years, resulted in the highest levels of fluoride, aluminum and sodium in vegetation near Cornwall Island's south shore (near bridge) to the neighbouring northeast of RMC. The fluoride results displayed a pattern of decreasing concentrations with increasing distance from RMC.

(2) Fluoride levels in unwashed foliage collected in August and in forage collected monthly (May - October) generally were reduced, being amongst the lowest to be detected since the survey began in 1969. The August foliar results for aluminum and sodium also were reduced compared to corresponding earlier years' (1982-85) results.

(3) The decrease in foliar contamination resulted in fewer exceedances overall of the Phytotoxicology foliage guidelines. Moreover, in contrast with previous years, the MOE Ontario forage criteria were not exceeded at any of the forage sites, including the Bridge site, where during each previous year since sampling on a six-month basis began (in 1978) at least one exceedance had been documented.

(4) On deciduous vegetation, fluoride-like injury was observed on most of the species injured in 1985. As in previous years, the most adverse effects generally were confined to the south shore immediate impact area of Cornwall Island. Overall, injured vegetation in the survey area displayed less severe injury in 1986 compared to previous years (1984 and 1985). Sweet corn plantings closest to RMC were free of the F-like injury observed in 1984 and 1985.

(5) On conifers, fluoride-like needle injury was confirmed only on red pine on the Noah Point property to the neighbouring northeast of the south shore bridge area.

In conclusion, the degree and extent of fluoride contamination to vegetation in the RMC survey area generally was reduced in 1986, with the August maple foliage results and monthly (May - October) forage results being amongst the lowest to be detected since the survey began. The severity of injury to vegetation also was slightly reduced, but overall, there was no dramatic change in the degree or extent of injury to vegetation in the survey area compared to other years. As in previous years, the highest degree of foliar contamination and most adverse injury to vegetation was confined to the south shore bridge area (immediate impact area) of the island, to the neighbouring northeast of RMC.

In view of the Environment Canada air monitoring results and the meteorological data previously discussed, it is suspected that the reduction in fluoride contamination found in 1986 was largely weather related.

B. **ALCOA Survey**

The major findings for the ALCOA survey area can be summarized as follows.

(1) Foliar fluoride levels in the Long Sault survey area were reduced in 1986 and were amongst the lowest to be detected since the start of the survey.

(2) The Phytotoxicology "upper limit of normal" guideline for fluoride in rural foliage (15 ppm) was exceeded only at Site 7 in 1986. For the first year since the survey began, the 35 ppm urban foliage guideline was not exceeded at any sites in the survey area.

(3) As in previous years, fluoride-like injury was observed only on wild grape foliage, with the injury observed throughout the survey area being very light overall.

In conclusion, foliar fluoride levels in the ALCOA survey area were reduced in 1986 and were amongst the lowest to be detected since the survey began in 1976. The reduced aluminum production at ALCOA since October 1985 likely has contributed to the decrease in foliar fluoride contamination found in the Long Sault survey area. However, as foliar fluoride levels in the nearby RMC survey area also were reduced in August (1986), it is believed that weather variations were largely accountable for the decrease in contamination found in both survey areas in 1986.

TABLE 1

Fluoride Results for Unwashed Manitoba Maple Foliage
Collected in the Cornwall Area Near the End of August: 1972-1986

Site No.	Site Location Is - Island M - Mainland	Approximate Distance (Km) and Direction from RMC	**Average Unwashed Fluoride Concentration (ppm - dry wt.)														
			1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982[a]	1983[a]	1984[a]	1985[a]	1986[a]
1	S Shore - E of Bridge(Is)	1.5 NE	451	597	516	1,171	550	750	193	197	143	192	380	293	389	337	159
33	A. Boots (Is)	1.9 NE	-	-	-	-	-	-	-	-	-	-	-	123	117	71	49
3	P. Hopps (Is)	3.1 NE	-	-	-	-	122	217	32	57	60	86	70	97	113	92	48
6	E. Benedict (Is)	4.1 NE	317	244	98	235	114	56	22	32	23	71	28	48	57	48	25
13	Cornwall (M)	6.0 NE	-	-	-	-	-	-	16	29	15	64	57	57	68	45	30
7	A. Lazore (Is)	6.8 NE	90	-	79	100	116	37	23	21	15	64	15	37	39	33	18
14	Cornwall (M)	8.3 NE	-	-	-	-	-	-	17	14	10	44	28	37	40	32	24
19	NE of Cornwall (M)	9.7 NE	-	-	-	-	-	-	18	18	20	50	25	30	34	35	19
17	NE of Cornwall (M)	13.2 NE	-	-	-	-	-	-	11	13	25	39	26	36	33	25	10
21	S Shore - W of Bridge (Is)	1.3 NNE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69
2	Customs (Is)	2.0 NNE	-	-	-	-	123	138	17	31	10	50	25	57	63	50	27
4	Cornwall (M)	4.7 NNE	-	-	-	-	-	-	29	34	45	45	66	63	42	27	22
5	Cornwall (M)	6.4 NNE	-	-	-	-	-	-	21	19	25	46	18	21	26	26	10
12	NE of Cornwall (M)	8.5 NNE	-	-	-	-	-	-	25	42	10	74	28	27	38	53	14
8	J. Thompson (Is)	1.9 N	30	-	76	60	29	45	15	21	8	18	12	27	23	32	19
9	R. Seymour (Is)	2.5 N	-	-	-	66	31	14	7	15	5	26	18	19	14	22	17
20	E End of Island (Is)	6.1 ENE	-	-	-	-	-	-	6	15	3	29	17	31	41	26	19

a Ion selective electrode method used; prior to 1982 the Alkali fusion method was used.

** Averages for 1975-79; 1983-86 are based on triplicate collections. A single composite sample was collected at each site in 1980-1982 and prior to 1975.

TABLE 2

Comparison of Particulate Removal Values for the Manitoba Maple Foliage Samples Collected in Late August 1982 through 1986, Based on the Unwashed (NW) and Washed (W) Fluoride Results

Site No.	General Location*	Distance (Km) and Direction from RMC	Per cent (%) Decrease in F Concentration (Particulate Removal) of Foliage due to Washing[a]				
			1982	1983	1984	1985	1986
1	S Shore - E of Bridge(Is)	1.5 NE	53	41	22	32	47
33	A. Boots (Is)	1.9 NE	-	50	32	17	18
3	P. Hopps (Is)	3.1 NE	31	30	6	10	25
6	E. Benedict (Is)	4.1 NE	29	48	33	33	0
13	Cornwall (M)	6.0 NE	58	54	26	31	7
7	A. Lazore (Is)	6.8 NE	0	59	36	18	0
14	Cornwall (M)	8.3 NE	57	38	20	47	0
19	NE of Cornwall (M)	9.7 NE	40	37	21	46	11
17	NE of Cornwall (M)	13.2 NE	46	39	27	28	0
21	S Shore - W of Bridge (Is)	1.3 NNE	-	-	-	-	19
2	Customs Area (Is)	2.0 NNE	48	79	8	36	26
4	Cornwall (M)	4.7 NNE	74	65	31	30	0
5	Cornwall (M)	6.4 NNE	33	43	19	35	0
12	NE of Cornwall (M)	8.5 NNE	54	63	32	51	0
8	J. Thompson (Is)	1.9 N	33	48	22	34	5
9	R. Seymour (Is)	2.5 N	17	32	14	27	18
20	E End of Island (Is)	6.1 ENE	29	55	32	31	21
Mean ± standard deviation			40 ±18	49 ±13	24 ±9	32 ±11	12 ±13

* (Is) - Cornwall Island; (M) - Mainland

[a] Calculated from the following formula: $\frac{NW - W}{NW} \times 100$

TABLE 3

Levels of Aluminum and Sodium in Unwashed Manitoba Maple Foliage Collected in August of 1982 through 1986

Site No.	General Location*	Distance (Km) and Direction from RMC	Concentration - parts per million - dry weight									
			Aluminum					Sodium				
			1982[1]	1983[3]	1984[3]	1985[3]	1986[3]	1982[1]	1983[3]	1984[3]	1985[3]	1986[3]
1	S Shore - E of Bridge(Is)	1.5 NE	174	181	193	217	127	520	373	480	420	137
33	A. Boots (Is)	1.9 NE	-	131	130	62	45	-	253	287	160	110
3	P. Hopps (Is)	3.1 NE	74	99	107	84	47	245	157	223	143	84
6	E. Benedict (Is)	4.1 NE	32	79	69	78	22	112	107	109	100	65
13	Cornwall (M)	6.0 NE	98	123	160	86	104	125	127	267	117	100
7	A. Lazore (Is)	6.8 NE	70	110	103	137	41	48	67	95	89	48
14	Cornwall (M)	8.3 NE	52	96	96	87	37	64	97	92	66	66
19	NE of Cornwall (M)	9.7 NE	100	121	153	96	51	128	103	83	58	68
17	NE of Cornwall (M)	13.2 NE	68	106	107	99	21	64	117	106	75	50
21	S Shore - W of Bridge (Is)	1.3 NNE	-	-	-	-	29	-	-	-	-	117
2	Customs (Is)	2.0 NNE	96	128	83	90	47	132	70	85	81	69
4	Cornwall (M)	4.7 NNE	90	130	100	61	44	130	97	87	67	63
5	Cornwall (M)	6.4 NNE	43	75	57	68	33	66	70	70	72	36
12	NE of Cornwall (M)	8.5 NNE	111	79	125	137	34	53	57	74	72	34
8	J. Thompson (Is)	1.9 N	51	96	57	115	35	85	77	68	64	39
9	R. Seymour (Is)	2.5 N	49	66	26	58	28	125	43	61	34	35
20	E End of Island (Is)	6.1 ENE	80	110	81	74	27	53	77	99	105	74

* (Is) Cornwall Island
(M) Mainland Cornwall Area

1 - based on a single sample collected at each site.

3 - mean of triplicate results for each site.

TABLE 4

Red Maple Foliage (Unwashed) Fluoride Results for 1986 Compared to Previous Years' Results for August

Location	Mean Fluoride Concentration (ppm - dry wt.)					
	June 17[2]	July 15[1]	August 11,[2] 1986	August 1985[2]	August 1984[3]	August 1982[1]
	South Shore Bridge Area Woodlots					
W of Bridge	20	74	37	22	134	118
E of Bridge	29	154	43	139	278	99
	To Neighbouring Northeast					
Noah Point	26	109	42	88	172	-

TABLE 5

White Pine (Current Year's Needles) Unwashed Fluoride Results for 1986 Compared to Previous Years' Results

Sample Location	Fluoride Concentration (ppm - dry wt. basis)			
	1982[3] Sept. 4	1984[1] Sept. 13	1985[2] Sept. 12	1986[2] Sept. 15
	South Shore Bridge Area			
West of Bridge	41	36	9	13
East of Bridge	59	34	13	30
	Centre of Island			
E. Benedict	23	11	6	8

[1] based on a single sample

[2] mean of duplicate sample results

[3] mean of triplicate sample results

TABLE 6

Monthly Fluoride Levels Detected in Unwashed Forage Collected on Cornwall Island and Mainland during 1986 and Corresponding Seasonal (May - Oct.) Means for 1978-1986

Site Location[b] (in order of increasing distance from RMC)	Monthly Mean Fluoride Concentration[1] (parts per million, dry weight)						Seasonal Mean Fluoride Concentration[a] 1978-1986 (parts per million, dry weight)								
	May	June	July	Aug.	Sept.	Oct.	1986[1]	1985[3]	1984[3]	1983[3]	1982[1]	1981[1]	1980[1]	1979[3]	1978[3]
Bridge Site (1.5 NE)* (uncut)	19	21	40	18	40	20	26	36	92	52	41	68	52	51	58
N. Point (2.0 NE) (grazed)	11	8	15	3	25	3	11	15	36	30	25	34	28	20	31
P. Hopps (3.1 NE) (grazed)	6	7	10	3	18	6	8	13	25	19	13	35	17	11	17
Dump Site (3.3 NE) (hayfield)	6	4	8	4	13	8	7	10	24	15	14	26	16	9	12
E. Benedict (4.1 NE) (grazed)	5	5	9	3	12	4	6	10	16	18	12	25	14	12	12
R. Pearce (4.6 NE) (grazed)	4	5	7	<2	6	<2	4	7	16	18	11	23	16	10	14
N. Hopps (5.7 NE) (hayfield)	3	3	6	<2	6	16	6	5	14	13	9	18	7	9	9
A. Lazore (6.8 NE) (hayfield)	3	2	9	<2	4	14	6	4	11	11	6	15	9	9	8
D. Farlinger (9.2 NE) (hayfield)	4	<2	10	<2	4	15	6	5	11	11	9	-	-	-	-
McGee (11.8 NE) (hayfield)	<2	<2	8	<2	<2	19	6	4	7	-	-	-	-	-	-
P. Caldwell (1.8 NNE) (hayfield)	7	<2	5	<2	4	5	4	7	15	12	13	-	-	-	-
J. Thompson (1.7 N) (grazed)	7	3	8	3	4	3	5	8	13	11	10	22	12	10	12
R. Seymour (2.5 N) (grazed)	3	<2	5	<2	5	4	4	4	9	9	7	21	7	6	8
W tip of Island (1.6 NNW) (hayfield/grazed)	5	<2	3	<2	4	2	3	4	9	8	7	-	-	-	-
Lunenburg (17.7 WNW)	<2	<2	4	<2	<2	<2	2	3	3	3	3	-	-	-	-

a - all 1982-1986 results based on Ion Selective Electrode method; Alkali Fusion Method used for analysis in 1978-81.
b - All sites are on the island, except Farlinger, McGee and Lunenburg sites.
1 - based on a single sample.
3 - based on triplicate samples.
* - approximate distance (Km) and direction from RMC.

TABLE 7

Average (June-July-August) Fluoride Results for Unwashed Forage Sampled on Cornwall Island - 1970-1986

Site Location (order of increasing distance from RMC)	*Average Fluoride Concentration (ppm - dry wt.)																
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982[a]	1983[a]	1984[a]	1985[a]	1986[a]
Bridge Site	597	361	137	128	192	-	-	88**	72	43	43	71	36	48	123	38	26
L. Point; N. Point	-	-	66	71	76	116	51	95	37	16	23	29	18	18	53	14	9
P. Hopps	-	-	-	-	-	-	32	30	20	9	18	37	10	18	36	12	7
Dump Site	-	-	-	-	-	-	-	-	13	6	12	26	9	10	31	7	5
E. Benedict	64	79	56	54	29	71	21	23	14	11	13	25	10	17	23	9	6
R. Pearce	-	-	-	-	-	-	-	-	14	10	15	22	8	17	21	6	5
N. Hopps	-	-	-	-	-	-	13	11	9	9	7	21	6	9	19	4	4
A. Lazore	-	-	11	14	13	21	11	13	9	8	7	15	5	7	12	3	4
Customs - Island Road (1977-1981)	-	-	-	-	-	-	-	19**	15	8	11	22					
P. Caldwell - 1982 on	-	-	-	-	-	-	-	-	-	-	-	-	8	7	18	7	3
J. Thompson	-	-	11	36	26	72	6	19	8	10	11	15	7	9	15	8	5
R. Seymour	18	14	7	-	28	38	7	14	6	5	8	17	5	7	10	3	3
W Tip of Island	-	-	-	-	-	-	-	-	-	-	-	-	4	6	9	3	2

* 1970-1974; 1980-1982 averages based on a single composite sample collected at each site per month.
1975-1979; 1983-86 averages based on the results of triplicate samples collected monthly at each site.

** average based on estimated level for June

[a] 1982-86 results based on Ion Selective Electrode method; in earlier years, the Alkali Fusion method was used.

TABLE 8

Results of Histological and/or Pathological Examination of Foliage Samples Collected from Cornwall Island During 1986

Sampling Date	General Location/ Property	Foliage Type	General Description of Injury	Results of Examination(s)		
		Samples Collected for Histological Examination		Typical of Fluoride	Some Similarity	Not Typical
June 17	S Shore - W of Bridge	Wild Grape	young leaves with interveinal spotting			X
	"	Staghorn Sumac	young leaves with interveinal necrosis			X
		"	mature leaves with interveinal necrosis			X
	S Shore - E of Bridge	Trembling Aspen	young leaves with interveinal & tip necrosis			X
		Red Maple	leaves with brownish marginal necrosis			X
		Choke Cherry	young leaves with reddish marginal necrosis	X		
July 16	N. Point	Plum	leaves with dark brown marginal necrosis		X(d)	
	A. Boots	Plum	leaves with reddish marginal necrosis		X(d)	
	"	Black Cherry	leaves with reddish marginal & interveinal spots		X(d)	
Sept. 12	S Shore - W. of Bridge	Black Cherry	leaves with reddish orange marginal necrosis and spots			X(d)
	A. Boots	Black Cherry	leaves with reddish spots (margins mainly)			X(d)
	N. Point	Red Pine	reddish tip necrosis on 1986 needles	X		
	Earny Benedict	White Pine	reddish tip necrosis on 1986 needles.			X(d)
		Samples Collected for Pathological Examination				
June 17	S shore - W of Bridge	Staghorn Sumac	leaves with interveinal black necrosis	No pathogen identified		
		Pin Cherry	leaves with scattered reddish spots	Leaf spot (Coccomyces Hiemalis)		
Sept. 12	S. shore - W of Bridge	Black Cherry	reddish spots on leaves	Shot hole (Coccomyces Lutescens)		
		Black Cherry	reddish spots (margins mainly)	No pathogen identified.		

(d) - diseased

TABLE 9

Percentage of Time Winds Were from the S, SW and W and Total Precipitation and Number of Days With Rain Recorded at The Ontario Hydro Climatic Station, Cornwall - May through August 1978-1986

Year	MAY					JUNE					JULY					AUGUST					MAY-AUGUST*				
	% Wind			Rain (mm)		% Wind			Rain (mm)		% Wind			Rain (mm)		% Wind			Rain (mm)		% Wind			Rain (mm)	
	S	SW	W	Tot	Freq.	S	SW	W	Tot	Freq.	S	SW	W	Tot	Freq.	S	SW	W	Tot	Freq.	S	SW	W	Tot	Freq.
1978	6	19	31	79	10	6	23	28	71	17	5	32	28	51	9	6	27	25	102	11	6	25	28	303	47 (8)
1979	7	18	19	64	14	6	28	27	41	10	4	27	31	48	10	7	29	24	130	16	6[a]	26[a]	25[a]	283[a]	50[a]
1980	6	19	23	39	7	3	17	33	38	12	5	25	33	114	19	5	21	22	137	13	5	21	28	292	49 (5)
1981	6	15	24	109	15	7	23	34	95	14	4	17	31	69	8	10	15	28	122	16	6	18	30	382	50 (5)
1982	9	11	19	58	8	5	23	20	86	14	2	24	34	66	10	3	23	33	125	12	5	20	26	324	42 (8)
1983	7	18	24	88	17	4	26	43	79	11	2	28	25	92	11	6	23	29	61	8	5	24	30	317	46 (4)
1984	3	17	39	113	18	4	22	38	55	8	2	26	48	51	11	2	23	34	95	14	3	21	40	296	47 (7)
1985	5	18	21	68	12	5	19	29	148	18	3	32	38	68	11	3	24	23	70	9	4	24	28	336	48 (6)
1986	6	13	20	90	18	2	18	31	108	13	2	13	32	165	14	7	24	29	104	16	4	17	28	466	60 (7)
Norms**	-			70	12	-			70	11	-			76	11	-			99	11	-			-	

* May through to and including date of regular maple foliage collection near end of August: 1978 - Aug. 29; 1979[a] - Sept. 5; 1980 - Aug. 27; 1981 - Aug. 26; 1982 - Aug. 25; 1983 - Aug. 23; 1984 - Aug. 23; 1985 - Aug. 28; 1986 - Aug. 27. a - 1979 May - August* values represent the period May - August 31.

** Rainfall normals taken from Canadian Climate Normals, Atmospheric Environment Service, Environment Canada, Toronto.

( ) Number of days with rain during the two-week period prior to maple collection.

TABLE 10

Analytical Fluoride Results for Unwashed Maple Foliage Collected in the Long Sault Area During 1976 to 1986

Site No.	Distance & Direction from ALCOA		*Fluoride Concentration (parts per million - dry weight)										
			1976 Sept. 1	1977 Aug. 29	1978 Aug. 29	1979 Sept. 6	1980 Aug. 28	1981 Aug. 26	1982 Aug. 26	1983 Aug. 23	1984 Aug. 22	1985 Aug. 28	1986 Aug. 27
1	4.8	N	34	17	15	59	5 (3)**	22 (12)**	16 (10)**	26 (14)**	25 (17)**	47 (31)**	13 (15)**
2	7.9	NNE	13	11	6	11	5 (3)	13 (12)	6 (5)	17 (8)	12 (11)	18 (13)	6 (6)
4	9.5	NE	91	45	29	47	25 (20)	50 (16)	16 (13)	33 (16)	61 (25)	28 (17)	13 (9)
7	9.6	NE	-	35	38	30	15 (5)	34 (12)	28 (22)	39 (23)	106 (62)	50 (35)	27 (25)
6	12.6	NE	57	33	16	13	15 (5)	9 (7)	9 (5)	19 (11)	41 (20)	17 (11)	9 (8)
8	7.1	ENE	-	16	20	16	3 (3)	24 (12)	17 (10)	18 (11)	48 (29)	18 (12)	10 (8)

* 1976-1979; 1983-1986 - average of triplicate samples
1980-82 - based on a single sample.

**( ) fluoride concentration of washed foliage.

AMBIENT AIR LEVELS OF FLUORIDE

AT CORNWALL ISLAND, ONTARIO

APRIL 15, 1986 - OCTOBER 14, 1986

SYNOPSIS

Fluoride monitoring was carried out over the 1986 Growing Season from April 15 to October 14 at Station 'B' located on the Benedict Farm.

Examination of the historical summary of the 24 hours average fluoride concentrations shows that the level of the particulate fluoride increased slightly from levels found in 1985 when record low concentrations were recorded. The concentrations of gaseous fluorides also indicate a slight increase from the low level recorded in 1985.

Gaseous fluoride concentrations greater than 0.85 ug/m^3 were recorded twice, the same as in 1985.

Exceedances of Ontario's criteria for air quality rose from 0.6% in 1985 to 1.3% in 1986. New York State air quality standards were not exceeded as in previous years. Canada's 24 hour gaseous objective for fluorides was exceeded twice representing 1.3% of the data. New York State weekly and monthly running average were not exceeded. Canada's 7, 30 and 70 day running averages were exceeded twice (1.2%), 8 times (5.2%) and 89 times (78.8%) respectively. Ontario's 24 hour total fluoride criteria of 1.63 ug/m^3 and its 30 day objective of 0.66 ug/m^3 were not exceeded.

Wind direction in 1986 was predominantly from the West (26.0%) as compared to South (22.2%) in 1985. Secondary and tertiary winds were from the East (17.9) and North West (12.0%) as compared to the South East (13.0%) and the North (9.6%) last year. Calm periods increased slightly from 17.2% in 1985 to 20.2% in 1986. Missing data represented 0.1% of the total winds as compared to 19.9% last year.

Pollution Roses indicate a higher particulate fluoride concentration with the wind blowing from the West under all wind conditions. Gaseous fluoride concentration were also higher with the wind blowing from West when the Consistency Index (CI) is greater than 84.

A review of the primary and secondary wind directions for the 1976 to 1984 growing seasons show the winds to be from the South West and West respectively. In 1985 primary and secondary winds shifted to the South and South East. During 1986 the primary wind direction was from the East with a slight increase in fluoride concentrations at Station 'B'. It is difficult to determine whether this increase is the result of a change in wind direction and/or an increase in fumigation at Reynolds.

Figure 1: Manitoba Maple Foliage And Forage Sites Sampled In The Reynolds Survey Area - 1986

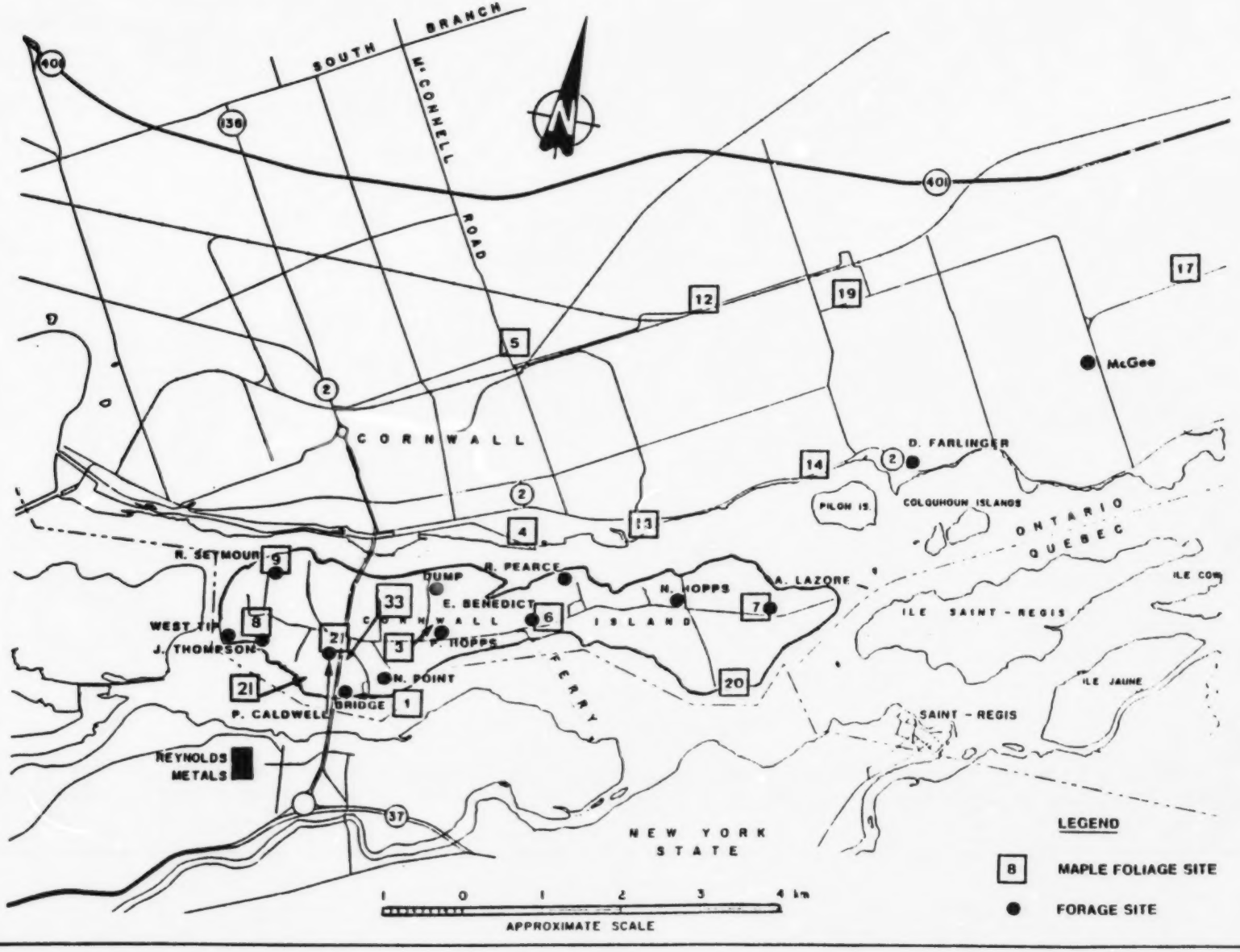

Figure 2: Approximate Location Of Other Tree Foliage Collection Sites In The Reynolds Survey Area And Of Manitoba Maple Foliage Sites To The North And Northeast Of ALCOA - 1986

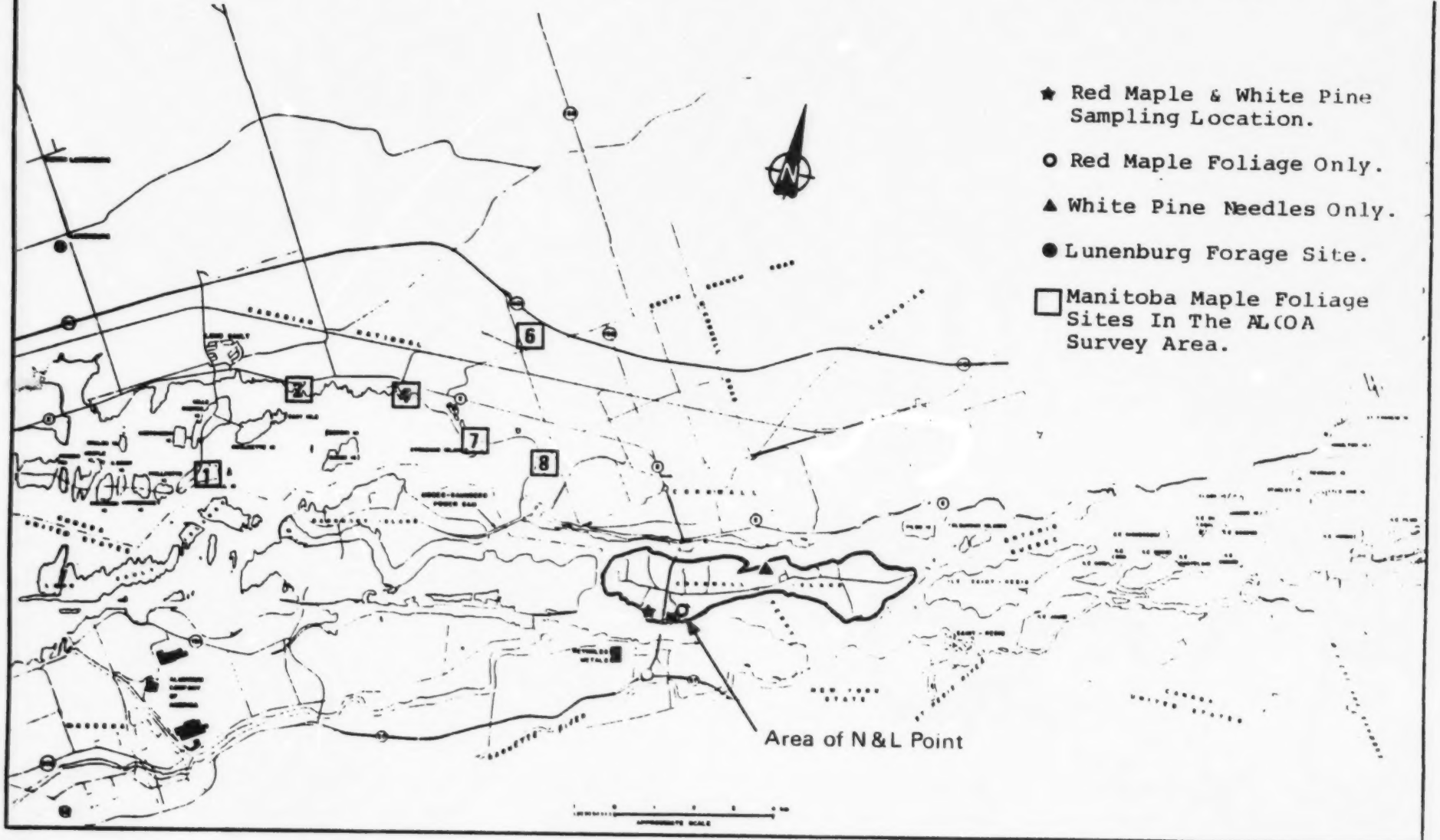

Figure 3: Other Locations Mentioned in 1985 and 1986 Reports.